

Immediate Lymphatic Reconstruction Via Supermicrosurgery During Breast Reconstruction: A Critical Review of Lymphedema Prevention and Clinical Outcomes

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ABSTRACT

Breast cancer-related lymphedema (BCRL) is a debilitating complication post axillary lymph node dissection (ALND). The clinical paradigm is changing from palliative decongestive therapies to primary surgical prevention. Immediate lymphatic reconstruction (ILR) by supermicrosurgery preempts lymphatic stasis before irreversible fibrosis occurs. We critically assessed current literature, combining information from randomized controlled trials (RCTs) and meta-analyses available up to 2026. Surgical procedures and clinical effectiveness will be examined in this review, with an emphasis on its contributions to adjuvant radiotherapy, Total Breast Anatomy Restoration (TBAR) and robotic-assisted supermicrosurgery. A large meta-analysis of 791 patients shows that ILR reduces the BCRL risk, producing a 69% reduction in incidence of lymphedema. Advanced intraoperative techniques (FITC mapping, vein grafts) and robotic platforms have fine-tuned anastomotic patency to 99.38%. Adjuvant radiotherapy delivers extensive ionizing doses to the micro-anastomosis, but the protective effect lasts. TBAR effectively combines vascularized lymph node transfer (VLNT) with autologous flaps for therapeutic reconstruction. ILR creates a new standard of care for high-risk patients. However, routine use in high-risk care needs to be risk stratified for cost-effectiveness. Improved research must focus on standardized diagnostic criteria and long-term studies of irradiated microvascular anastomoses.

KEYWORDS: Breast Cancer-Related Lymphedema; Immediate Lymphatic Reconstruction; Supermicrosurgery; Lymphovenous Anastomosis; Total Breast Anatomy Restoration; Robotic Microsurgery.

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INTRODUCTION

With the development of targeted therapeutics and advanced oncoplastic techniques, breast cancer survival rates have reached unprecedented levels. Yet, such longevity has unmasked chronic ailments: particularly breast cancer-related lymphedema (BCRL) (1). BCRL appears in up to 40% of ALND and regional nodal irradiation (RNI) patients and imposes heavy physical and psychological demands (1,

2). Historically, management has been done with complex physical decongestive therapy (CDT), whereby a reduced fluid accumulation is temporarily achieved but still cannot arrest the biological progression of lymphatic fibrosis (2). Within the last decade, reconstructive supermicrosurgery has led to a paradigm shift toward primary surgical prophylaxis (3). Immediate lymphatic reconstruction (ILR) as initially known was created as the LYMPHA approach by creating

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prophylactic lymphovenous bypass (LVB) during ALND. ILR shunts transected lymphatics directly into the axillary venous system, precluding the initial fluid stasis that drives BCRL (3). This critical review aims to systematically assess ILR, surgical advancement, robotic support, and economic constraints to global implementation.

PATHOPHYSIOLOGY AND RATIONALE

BCRL is a dynamic, T-cell-mediated inflammatory disease process (2). The initial mechanical blockade of ALND leads to the pooling of protein-rich lymph fluid, which acts as a sustained immunologic trigger. This localized stasis stimulates a cytokine cascade that upregulates fibrogenic mediators like TGF- β 1, actively inhibiting lymphatic endothelial cell proliferation (2).

Concurrently, this protein-rich fluid stimulates surrounding adipocyte hypertrophy, transitioning the limb from a fluid-predominant state to dense fibro-adipose deposition (2). Once this "vicious cycle" of inflammation and fibrosis alters the native tissue architecture, the disease becomes essentially irreversible. ILR perfectly exploits the subclinical window of opportunity; by bypassing the disrupted lymphatics at the moment of injury, it permanently aborts the CD4+ T-cell inflammatory cascade before macroscopic swelling occurs (2, 3).

SURGICAL TECHNIQUES AND INNOVATIONS

The execution of ILR requires the highest echelons of supermicrosurgical proficiency, manipulating vessels frequently measuring less than 0.8 mm (4, 5).



Figure 1. Immediate Lymphatic Reconstruction (ILR) Anastomosis.

Intraoperative view showing a transected lymphatic channel anastomosed to an axillary recipient vein branch. Successful anastomosis is confirmed by visualizing the dye flowing freely across the anastomosis into the recipient vein (3).

Intraoperative Mapping

High-fidelity mapping is non-negotiable. While indocyanine green (ICG) lymphangiography under near-infrared (NIR)

light is standard, it requires dimming operating room lights, disrupting workflow (4). Recent innovations utilize Fluorescein Isothiocyanate (FITC), which is excitable within the visible light spectrum. Utilizing a 560-nm optical filter on the operating microscope allows surgeons to visualize fluorescent lymphatics within a fully illuminated field (4).

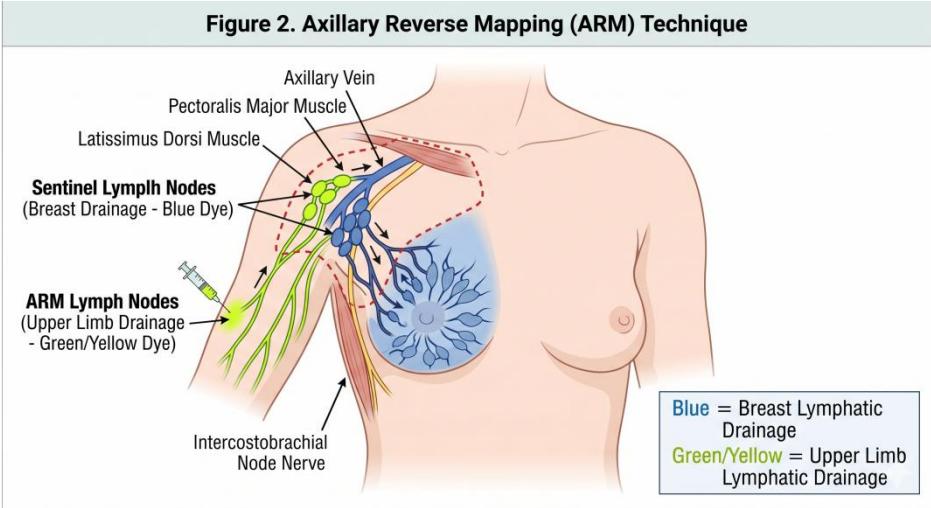


Figure 2. Axillary Reverse Mapping (ARM).

Schematic representation of the ARM technique, enabling the discrimination and preservation of the lymphatic drainage originating from the upper limb during an ALND, segregating it from the nodal drainage of the breast tissue (3).

Anastomotic Configurations and Vein Grafts

The typical ILR setup is in an intussusception (telescoping) configuration to account for size discrepancies between sub-millimeter lymphatics and larger axillary veins, which protect the delicate lymphatic endothelium against venous turbulence

(3, 5). One of the major challenges is the absence of a proper recipient vein without tension. Surgeons are increasingly using interposition vein grafts taken from the lower extremity. Such grafts eliminate tension, permit better size matching, and importantly, contain a naturally functioning valve that serves as a biological one-way gate, definitively protecting the lymphatic channel from venous hypertension (5). Mechanical microvascular venous couplers (5) dramatically speed up proximal anastomoses.

CLINICAL OUTCOMES AND RADIOTHERAPY IMPACT

The clinical efficacy of ILR is now supported by robust Level I evidence and expansive meta-analyses (6, 7).

Study Characteristic	Stav Brown et al. (2026) Meta-Analysis (6)	Coriddi et al. (2023) RCT (7)	He et al. (2025) Meta-Analysis (8)
Study Design	Meta-analysis of 9 Prospective Trials	Level 1 Randomized Controlled Trial	Systematic Review and Meta-Analysis
Total Cohort	791 (460 ILR vs. 331 Control)	144 (72 ILR vs. 72 Control)	12 published studies analyzed
BCRL Incidence (ILR)	9% (95% CI: 1-16%)	9.5%	8.6% (95% CI: 6-12%)
BCRL Incidence (Control)	29% (95% CI: 11-46%)	32.0%	Significantly higher than ILR
Risk Metrics	OR: 0.31; RR: 0.42	P = 0.014	OR: 0.14 (P < 0.001)

Stav Brown et al., the definitive 2026 meta-analysis, showed that ILR yields a 69% reduction in the odds of developing lymphedema (OR 0.31). In a similar vein, Coriddi's RCT demonstrated a drastic decrease in BCRL incidence from 32% (control) to 9.5% (ILR) at 24 months, utilizing highly objective relative volume change (RVC) criteria (7). A major concern is the effect of adjuvant regional nodal irradiation (RNI) on the fragile micro-anastomosis. Prospective dosimetric studies using intraoperative radiopaque "twirl clips" recently demonstrated that ILR anastomoses are often situated in the targeted radiation fields, receiving a median dose of 3939 cGy (9). Surprisingly, no catastrophic delayed

failure is observed on clinical outcomes indicating that the intussusception technique and continuous flow volume offer an unexpected radio-resistance (9).

TOTAL BREAST ANATOMY RESTORATION (TBAR)

For patients who are already suffering from established BCRL and seeking autologous breast reconstruction, the "Total Breast Anatomy Restoration" (TBAR) paradigm seamlessly integrates Vascularized Lymph Node Transfer (VLNT) with a Deep Inferior Epigastric Perforator (DIEP) flap (10).

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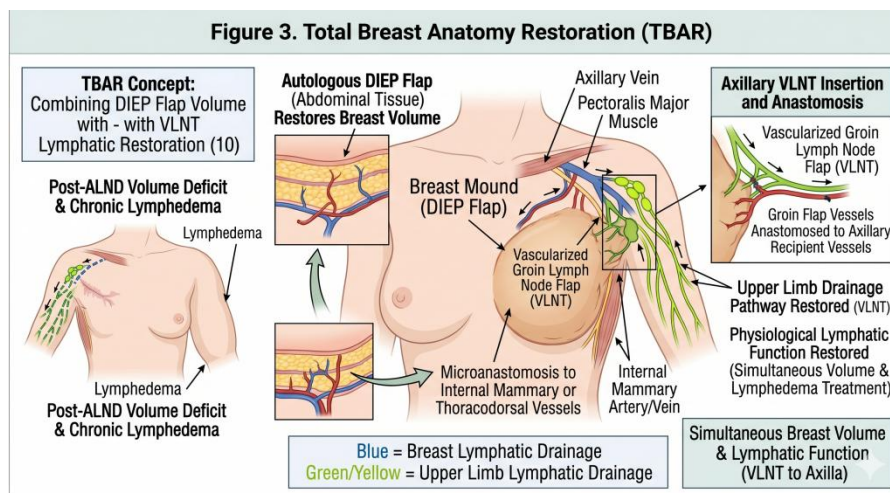


Figure 3. Total Breast Anatomy Restoration (TBAR).

Diagram illustrating the TBAR concept, combining autologous DIEP flap breast reconstruction with a VLNT to simultaneously restore breast volume and physiological lymphatic function (10).

Lymphovenous Anastomosis (LVA) functions entirely as a mechanical shunt that brings rapid early relief, while the VLNT acts biologically. Transferred nodes have the potential to absorb interstitial fluid and constitutively secrete vascular endothelial growth factor-C (VEGF-C), resulting in profound regional lymphangiogenesis that peaks at approximately 18

months postoperatively (10, 11). TBAR delivers highly significant reductions in limb volume and permits the discontinuation of compression garments in a single, unified surgical intervention (11).

ROBOTIC-ASSISTED SUPERMICROSURGERY

When human physical ability has been tested to its limits, the field is seeing the adoption of specialized supermicrosurgery robots such as the Symani Surgical System and MUSA-2 (12, 13).



Figure 4. Robotic-Assisted Supermicrosurgery. The Symani Surgical System, a dedicated supermicrosurgical robotic platform featuring motion-scaling and tremor reduction, utilized to perform high-precision lymphovenous anastomoses (13).

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These platforms enable absolute tremor elimination and customizable motion scaling allowing one to manipulate ultra fine 11-0 or 12-0 sutures without tearing tissue (13). A 2025 systematic review showed that robotic-assisted procedures drastically reduced rates of intimal microtrauma with nearly

perfect mean anastomotic patency of 99.38%. Currently, operating times are longer than manual techniques, but the accelerated learning curve indicates rapid future normalization (12).

HEALTH ECONOMICS

The extensive utilization of ILR and its use is under a brutal economic microscope. In a 2025 decision-analytic approach in ILR in a well-developed healthcare system, routine,

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universal ILR produced a staggering Incremental Cost-Effectiveness Ratio, or ICER, well in excess of US\$200,000 per QALY, beyond existing willingness-to-pay guidelines. Since 60% to 80% of the ALND patients will naturally never develop BCRL, its universal application cannot be economically viable (14). To be cost-effective, ILR should be aggressively targeted by the threat of ultra-high-risk cohorts identified with predictive models and based on BMI, nodal burden, and dosimetric blueprints (14, 15).

CONCLUSION

Immediate Lymphatic Reconstruction can effectively terminate the progressive, inflammatory cascade of BCRL, demonstrating a massive 69% reduction in the odds of disease onset. With robust Level I evidence, it also sets a new standard of care for high-risk patients undergoing ALND. FITC mapping, interposition vein grafts, and robotic-assisted platforms have over time largely overcome technical limitations. TBAR provides a potent therapeutic alternative for established disease. For its global scalability in the future, the focus needs to be on standardizing diagnostic metrics along with mitigating radiotherapy impacts and defining AI-driven risk-stratification models to ensure absolute economic viability.

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